A METHOD OF IDENTIFYING WORKSTATIONS THAT PERFORMED WORK ON A WORKPIECE

BACKGROUND OF THE INVENTION

The present invention generally relates to the identification of workpieces and more specifically to a method of identifying workstations that performed work on a workpiece.

It is known to provide a marking system that marks a finished workpiece to identify the model of the workpiece, the production run that produced the workpiece and/or the order of production of the workpiece. An example of such a marking process for a vehicle frame is disclosed in U.S. Patent No. 5,202,836 to Iida et al., which is assigned to the assignee of the present application. If a defect later appears in the workpiece, such a mark helps identify when the workpiece was finished, which provides some help in identifying the source of the defect. In a typical manufacturing operation, however, a plurality of workstations work on a workpiece. Moreover, there are typically a plurality of workstations that perform the same operation or process. Thus, a workpiece may, for example, have a particular drilling operation performed on it by one of a plurality of drilling machines. As a result, even if the particular drilling operation is identified as the source of a defect in the workpiece, the defect may have been caused by any one of the drilling machines. Conventional marking systems, such as the type identified above, fail to provide a mark or marks that can identify a particular workstation as having performed an operation on a particular workpiece.

Accordingly, there is a need in the art for a method of identifying workstations that performed work on a workpiece. The present invention is directed to such a method.

SUMMARY OF THE INVENTION

In accordance with the present invention, a method is provided for identifying workstations that performed work on a workpiece in a work line having

a plurality of zones, wherein each zone includes a plurality of workstations that perform the same type of operation. In accordance with the method, a unique code is provided for identifying each workstation. After work is performed on the workpiece in one of the workstations in one of the zones, the workpiece is marked with the unique code for the workstation. The workpiece is then moved to a following zone. This procedure is repeated for the other zones in the work line. Each of the unique codes is a mark and the location of the mark on the workpiece.

In accordance with the present invention, in a first one of the zones, a workpiece is moved from a first input area to a first workstation. The workpiece is worked on in the first workstation and then is moved to a first output area in the first one of the zones. At the first output area, the workpiece is marked with a first mark indicating that the first workstation worked on the workpiece. The workpiece is then moved to a second input area in a second one of the zones and from there, is moved to a second workstation in the second one of the zones. The workpiece is worked on in the second workstation and then is moved to a second output area in the second one of the zones. At the second output area, the workpiece is marked with a second mark indicating that the second workstation worked on the workpiece. The workpiece is moved to the first workstation and to the first output area by a first autoloader, while the workpiece is moved to the second workstation and to the second output area by a second autoloader.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawings where:

Fig. 1 shows a side elevational view of an autoloader;

Fig. 2 shows a top plan view of a portion of a machining line including the autoloader;

Fig. 3 shows a perspective view of a portion of the autoloader and a quality control station;

Fig. 4 shows a front view of a control panel for the quality control station;

Fig. 5 shows a flow chart of a portion of a supply routine;

Fig. 6 shows a flow chart of another portion of the supply routine;

Fig. 7 shows a flow chart of a quality control routine;

Fig. 8 is a diagram graphically showing how the supply routine operates;

Fig. 9 is a schematic view of a crankshaft disposed at a drop-off station adjacent to a stamping machine;

Fig. 10 is an end view of a first end of a crankshaft showing marking areas and positions; and

Fig. 11 is an end view of a second end of a crankshaft showing marking areas and positions.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

It should be noted that in the detailed description that follows, identical components have the same reference numerals, regardless of whether they are shown in different embodiments of the present invention. It should also be noted that in order to clearly and concisely disclose the present invention, the drawings may not necessarily be to scale and certain features of the invention may be shown in somewhat schematic form.

As used herein, the term "chronological order" shall mean the order in which events occur, beginning with the oldest event first and ending with the most current event.

The present invention is directed to a method of identifying workstations that performed work on a workpiece during a production run in which workpieces are supplied to the workstations by workpiece conveyance apparatus. The conveyance apparatus may be an autoloader, such as an autoloader 10 shown best in Fig. 1. The autoloader 10 is operable to move workpieces to and from a plurality of workstations MC1, MC2, MC3, MC4 and to load and unload the workpieces into and from the workstations MC1-MC4. The workstations MC1-MC4 may be machines grouped in a zone 20 of a machining line 22, such as a machining line for producing automotive crankshafts. In such an application, the

workpieces are automotive crankshafts and the workstations MC1-MC4 in the zone 20 perform machining operations on the crankshafts. Preferably, the workstations MC1-MC4 all perform the same machining operation. For purposes of illustration, the workstations MC1-MC4 may all be drilling machines for drilling cross oil passage holes in a crankshaft. It should be appreciated, however, that the present invention is not limited to a particular operational environment, such as a crankshaft machining line, but rather has numerous applications, as will be understood by those of skill in the art.

Referring now to Fig. 2, the machining line 22 includes a plurality of zones in addition to the zone 20. For purposes of brevity, however, only a portion of the zones are shown. More specifically, only the zone 20 and a preceding zone 24 and a following zone 26 are shown. As set forth above, the zone 20 includes the autoloader 10, which services workstations MC1-MC4. The zone 20, however, also includes a second autoloader 28 and workstations MC5, MC6, MC7 and MC8. The preceding and following zones 24, 26 include autoloaders 30, 32 respectively, and the other zones each have at least one autoloader, as well. The autoloaders 28, 30, 32 and the other autoloaders have substantially the same construction and operation as the autoloader 10, whose construction and operation will be discussed in more detail below. The zone 20 is connected to the preceding zone 24 by an input conveyor 34 and is connected to the following zone 26 by an output conveyor 36. The input conveyor 34 is operable to support and carry workpieces that have been worked upon in the preceding zone 24 to the zone 20, whereas the output conveyor 36 is operable to support and carry workpieces that have been worked upon in the zone 20 to the following zone 26. The workpieces are preferably disposed on pallets when they are carried by the input and output conveyors 34, 36.

The input and output conveyors 34, 36 may be conventional roller conveyors supported above a floor 38. In addition to moving workpieces, the input and output conveyors 34, 36 act as buffers to hold workpieces. For example, if all or a portion of zone 20 is taken down for maintenance or other reasons, the output conveyor 36 should have sufficient capacity to hold

workpieces from zone 20 to continue feeding the workpieces to following zone 26. In this manner, the downtime on zone 20 will have minimum impact on following zone 26. Since the capacity to hold workpieces is determined by the lengths of the input and output conveyors 34, 36, the lengths of the input and output conveyors 34, 36 are selected to provide a desired amount of buffering.

As set forth above, the machining line 22 may produce automotive crankshafts and in accordance therewith, the workstations M1-M8 in zone 20 may all be drilling machines for drilling cross oil passage holes in a crankshaft. In such an application, the preceding zone 24 may include a plurality of workstations MC9, MC10, MC11, which are gundrill machines for drilling slant oil passage holes, and the following zone 26 may include a plurality of workstations MC12, MC13, which are multiwheel grind machines for grinding main journals and post ends of a crankshaft.

When a workpiece moves through the machining line 22, only one workstation in a zone works on the workpiece. After the workpiece is worked on in a zone by one of the workstations located therein, the workpiece is then moved to a succeeding zone, where the workpiece is worked on by one of the workstations located therein. This procedure continues until the workpiece travels through the entire machining line 22 and is thereby finished: Thus, with regard to the portion of the machining line shown in Fig. 2, a workpiece is worked on by one of the workstations MC9, MC10, MC11 in the preceding zone 24 and then is moved by the autoloader 30 and the input conveyor 34 to the zone 20. In zone 20, the workpiece is worked on by one of the workstations MC1-MC8 and then is moved by the autoloader 10 or the second autoloader 28 and the output conveyor 36 to the following zone 26. In the following zone 26, the workpiece is worked on by one of the workstations MC12 and MC13 and then is moved to the next zone.

Each of the workstations MC1-M13 and the other workstations in the machining line 22 is operable to generate a call signal indicating that the workstation is ready to receive and work upon a workpiece (crankshaft). Each of the workstations MC1-M13 and the other workstations in the machining line 22 is

also operable to generate an error signal indicating that there is a problem with the workstation or the workstation is off-line and that a workpiece (such as a crankshaft) should not be loaded into the workstation. A control system 40 for the autoloader 10 is electrically connected by wiring (not shown) to the workstations MC1-MC4 and is operable to receive the call and error signals from the workstations MC1-MC4. As will be discussed further below, the control system 40 uses the call and error signals to control the operation of the autoloader 10.

In the zone 20, the workstations MC1-MC8 are spaced apart and arranged in a pair of lines. Similarly in the preceding zone 24, the workstations MC9-11 are spaced apart and arranged in a line, and in the following zone 26, the workstations MC12, MC13 are spaced apart and arranged in a line. The zone 20, the preceding zone 24 and the following zone 26 are arranged in a parallel and spaced-apart manner. Thus, the input and output conveyors 34, 36 extend in perpendicular fashion between the preceding zone 24 and the zone 20 and the zone 20 and the following zone 26, respectively. The input and output conveyors 34, 36 are disposed relatively close to each other, toward a conveyor end 20a of the zone 20.

Referring back to Fig. 1 and now also to Fig. 3, the autoloader 10 includes a carriage 50 that is mounted to, and movable along, a guidance structure that defines a path of travel between the workstations MC1-MC4. The guidance structure can include at least one rail, such as an overhead monorail 52 supported on pillars 54 extending upwardly from the floor 38, as shown. Alternately, the monorail 52 can be suspended from a ceiling. The carriage 50 is moved along the monorail 52 by a servomotor (not shown). The carriage 50 is provided with a lowerator 56 for loading and unloading workpieces to and from the workstations MC1-MC4. The lowerator 56 is driven by pneumatic cylinders or other drive means to vertically move between an upper or travel position and a lower or servicing position. The lowerator 56 includes a pair of grippers 58, 60 for holding workpieces. The carriage 50 is connected to the control system 40 by wiring 62. As will be discussed further below, the control system 40 is operable

to control the movement of the carriage 50 along the monorail 52 and to control the movement and operation of the lowerator 56 and the grippers 58, 60.

The monorail 52 is spaced above and extends over the workstations MC1-MC4. Since the workstations MC1-MC4 are arranged in a line, the monorail 52 is linear. It should be appreciated, however, that if the workstations MC1-MC4 are arranged in a different configuration, the monorail 52 will have a correspondingly different configuration, as well. Each workstation MC1-MC4 has an entrance area that faces upwardly toward the monorail 52. As will be described further below, workpieces are loaded into the workstations MC1-MC4 by the lowerator 56 through the entrance areas. At each of the workstations MC1-MC4, a shutter door 64 is disposed between the monorail 52 and the entrance area of the workstation. Each shutter door 64 is movable between a closed position, wherein the shutter door 64 is disposed between the monorail 52 and the entrance area, and an open position, wherein the shutter door 64 is not disposed between the monorail 52 and the entrance area. When the shutter door 64 of one of the workstations MC1-MC4 is in the closed position, the shutter door 64 prevents the lowerator 56 from entering the workstation through the entrance area. Each shutter door 64 is provided with a set of electrical contacts that are electrically connected to the control system 40 for the autoloader 10. The electrical contacts are operable to provide the control system 40 with control signals that inform the control system 40 whether the shutter door 64 is open or closed.

Referring back to Fig. 2, at the end of the input conveyor 34 is a first input area 66, which is a vertically-movable substrate from which the autoloader 10 obtains workpieces for loading into the workstations MC1-MC4. At the end of the output conveyor 36 is a second input area 70, which is a vertically-movable substrate from which the autoloader 32 obtains workpieces for loading into the workstations MC12 and MC13. The first and second input areas 66, 70 are each moved by a pneumatic cylinder or other lift means. It should be noted that the other zones in the machining line 22 also have one or more input areas from which the autoloader(s) in the zones obtain workpieces.

At the beginning of the output conveyor 36 is a drop-off station 68. Similarly, at the beginning of an ouput conveyor 72 for the following zone 26 is a second drop-off station 74. Drop-off station 68 is a vertically-movable substrate upon which workpieces from the workstations MC1-MC4 are deposited by the autoloader 10, while second drop-off station 74 is a vertically-movable substrate upon which workpieces from the workstations MC12 and MC13 are deposited by the autoloader 32. It should be noted that the other zones in the machining line 22 also have one or more drop-off stations for receiving workpieces from the autoloader(s) in the zones.

Referring now also to Fig. 9, the drop-off station 68 is moved by a pneumatic cylinder 76 or other lift means. The drop-off station 68 is movable between a lowered position and a raised position. When the drop-off station 68 is moved to the lowered position, a workpiece (such as a crankshaft 250) disposed on the drop-off station 68 moves onto the output conveyor 36. When the drop-off station 68 is in the raised position, a workpiece disposed on the drop-off station 68 is accessible by a stamping machine 80. Although not shown, the second drop-off station 74 and the other drop-off stations in the machining line 22 have the same or substantially the same construction as the drop-off station 68 and are accessible by stamping machines (having the same or substantially the same construction as the stamping machine 80) or other type of marking device. For example, in lieu of a stamping machine, a zone may have a drill that marks the workpiece with small holes.

The stamping machine 80 is preferably a pneumatic pin marking machine, such as is available from Telesis Controls Corporation. The stamping machine 80 may be constructed in accordance with U.S. Patent No. 4,506,999, which is hereby incorporated by reference. The stamping machine 80 uses an array of pneumatically driven marker pins to make a plurality of indentations in a workpiece so as to form a stamp or mark. The stamping machine 80 is operatively connected to the control system 40 for receiving command signals therefrom. The stamping machine 80 is operable to form a mark for each of the workstations MC1-MC4 . As will be discussed further below, when the autoloader

10 moves a workpiece from one of the workstations MC1-MC4 to the drop-off station 68, the stamping machine 80 stamps the workpiece with a mark identifying the workstation. Similarly, when the autoloader 32 moves a workpiece from one of the workstations MC12 and MC13 to the second drop-off station 74, the stamping machine disposed adjacent thereto stamps the workpiece with a mark identifying the workstation. This same procedure occurs at each of the drop-off stations in the machining line 22 having a stamping machine.

A quality control (QC) station 90 is located toward the output conveyor 36, near the drop-off station 68. Referring now to Fig. 3, the QC station 90 includes a cage 92 defining an interior space 94 for receiving the lowerator 56 of the carriage 50. A tray 96 with pivotable cover 98 is secured to a front wall of the cage 92. A workpiece jig 100 is movably mounted to the cage 92 and is movable between a retracted position, wherein the workpiece jig 100 is disposed in the interior space 94 of the cage 92, and an extended position, wherein the workpiece jig 100 is disposed in the tray 96. When the workpiece jig 100 is in the retracted position, the workpiece jig 100 is positioned to receive a workpiece from the lowerator 56. The workpiece jig 100 is constructed to hold a workpiece, such as a crankshaft.

Referring now also to Fig. 4, a quality control (QC) panel 102 is disposed proximate to the QC station 90. The QC panel 102 includes a plurality of operator interface devices in the form of a main selector switch 104, a lamp check light 106, a plurality of lighted request pushbuttons 108a, 108b, 108c, 108d and a plurality of lighted bypass pushbuttons 110a, 110b,110c, 110d. The operator interface devices are electrically connected to the control system 40 by wiring (not shown) and are operable to transmit control signals to the control system 40 in response to manipulation by an operator, as will be further described below. The main selector switch 104 is operable to select a desired QC function and is movable between a "LOAD" position, an "UNLOAD" position and a "CVYR" position. The request pushbuttons108a-d are operable for selecting the workstation for which the QC function is desired, while the bypass pushbuttons 110a-d are operable for putting a desired workstation in a bypass mode.

The main selector switch 104 operates in conjunction with the request pushbuttons 108a-d to generate QC signals for the workstations MC1-MC4. For example, when the main selector switch 104 is set to the LOAD position and the request pushbutton 108a for MC1 is depressed, a workstation load signal is generated for MC1 and transmitted to the control system 40. When the main selector switch 104 is set to the UNLOAD position and the request pushbutton 108b for workstation MC2 is depressed, a workstation unload signal is generated for workstation MC2 and transmitted to the control system 40. When the main selector switch 104 is set to the CVYR position and the request pushbutton 108c for workstation MC3 is depressed, a drop-off signal is generated for workstation MC3 and transmitted to the control system 40.

The control system 40 uses the workstation load signal, the workstation unload signal and the drop-off signal to control the autoloader 10 to move workpieces to and from the QC station 90, as will be discussed in more detail below. Briefly, however, when a workstation load signal is received for, say workstation MC1, the control system 40 controls the autoloader 10 such that the autoloader 10 completes its current cycle and then picks up a workpiece from the QC station 90 and moves it to workstation MC1. When a workstation unload signal is received for, say workstation MC2, the control system 40 controls the autoloader 10 such that the autoloader 10 completes its current cycle and then picks up a workpiece from workstation MC2 and moves it to the QC station 90. When a drop-off signal is received for, say workstation MC3, the control system 40 controls the autoloader 10 such that the autoloader 10 completes its current cycle and then picks up a workpiece from the QC station 90 and moves it to the drop-off station 68, where the workpiece is stamped by the stamping machine 80 with a mark indicating that the workpiece was worked on by workstation MC3, as will be described more fully below.

When the control system 40 receives a workstation load signal or a workstation unload signal for one of the workstations MC1-MC4, the control system 40 places the workstation in a bypass mode, which is indicated by a flashing light on the lighted bypass pushbutton 110 for the workstation. When

one of the workstations MC1-MC4 is in the bypass mode, an error signal is generated for the workstation and transmitted to the control system 40. As will be described further below, when the control system 40 receives an error signal from one of the workstations MC1-MC4, the control system 40 removes the workstation from the autoloader supply routine 120, i.e., the control system 40 controls the autoloader 10 so that it will not supply workpieces to the workstation.

Each of the workstations MC1-MC4 can also be placed in the bypass mode by depressing the bypass pushbutton 110 for the workstation. After one of the workstations MC1-MC4 is placed in the bypass mode by either the control system 40 or by the depression of its bypass pushbutton 110, the workstation stays in the bypass mode until the operator restarts the workstation. If the workstation was placed in the bypass mode for an inspection of one the workpieces the workstation worked on, the operator typically does not restart the workstation until after the operator verifies the quality of the workpiece.

The foregoing control scheme is used to inspect workpieces for quality control purposes. For example, if an operator desires to check the quality of the operation performed by workstation MC1, the operator moves the workpiece jig 100 to the retracted position, then moves the main selector switch 104 to "UNLOAD" and depresses the request pushbutton 108a for MC1. In response, the autoloader 10 completes its current cycle and then delivers a workpiece that has been worked upon in workstation MC1 to the workpiece jig 100 at the QC station 90. The workstation MC1 is then placed in the bypass mode by the control system 40. The operator then moves the workpiece jig 100 to the extended position and opens the cover 98. The operator may inspect the workpiece while it is being held by the workpiece jig 100, or, more preferably, the operator may inspect the workpiece outside the tray 96 on a stand alone jig (not shown). The operator preferably uses a hoist (not shown) located outside the cage 92 to move the workpiece to the stand alone jig. When the workpiece is situated in the desired inspection location, the operator inspects the workpiece, such as for compliance with certain specifications. If the workpiece passes the inspection (such as by fully meeting the specifications), the operator loads the

workpiece back into the workpiece jig 100 and moves the work piece jig 100 to the retracted position. The operator then moves the main selector switch 104 to the "CVYR" position and depresses the request pushbutton 108a for workstation MC1. In response, the autoloader 10 completes its current cycle and then delivers the inspected workpiece to the drop-off station 68, where it is stamped with a mark indicating that the workpiece was worked on by workstation MC1. The operator then restarts the MC1 workstation to take it out of the bypass mode.

If the workpiece does not pass inspection (such as by not meeting the specifications), but the operator believes that the workpiece can pass inspection if the workpiece is reworked in MC1 (or another desired workstation), the operator loads the workpiece back into the workpiece jig 100 and moves the work piece jig 100 to the retracted position. The operator then moves the main selector switch 104 to the "LOAD" position and depresses the request pushbutton 108a for workstation MC1 (or the request pushbutton for the other desired workstation). In response, the autoloader 10 completes its current cycle and then returns the inspected workpiece back to workstation MC1 (or delivers it to the other desired workstation), where it is reworked.

If, from inspection, the operator determines that the workpiece does not meet the specifications and cannot be reworked, the operator simply moves the workpiece to a scrap area (not shown).

Wherever practical, a quality control (QC) station is provided for each of the other autoloaders in the machining line 22. In this manner, most zones in the machining line 22 have at least one QC station. If the nature of a zone or sub-zone serviced by an autoloader is such that a workpiece can easily be inspected on an output conveyor and the workpiece will not be returned to the zone or sub-zone for rework, a QC station is not provided for the autoloader in the zone or sub-zone. For each of the autoloaders in the zones and sub-zones having a QC station, the QC station is preferably located toward a conveyor end of the autoloader, i.e., the end of the autoloader disposed next to input and output conveyors.

With regard to the portion of the machining line 22 shown in Fig. 2, a QC station 112 is provided for the second autoloader 28, while a QC station 114 is provided for the autoloader 30 in the preceding zone 24 and a QC station 116 is provided for the autoloader 32 in the following zone 26. The QC stations 112-116 and the other QC stations in the machining line 22 preferably have substantially the same construction and operation as the QC station 90. Quality control (QC) panels (not shown) having substantially the same construction and operation as the QC panel 102 are disposed proximate to the QC stations 112-116 and the other QC stations in the machining line 22, respectively. These QC panels are operably connected to control systems for the second autoloader 28, the autoloaders 30, 32 and the other autoloaders, and interact with the control systems in substantially the same manner that the QC panel 102 interacts with the control system 40. In this regard, it should be noted that the control systems for the second autoloader 28, the autoloaders 30, 32 and the other autoloaders have substantially the same construction and operation as the control system 40.

The control system 40 for the autoloader comprises a programmable logic controller (PLC). A Q series PLC from Mitsubishi Automation, and, more specifically, a Mitsubishi Q2AS CPU s-1, has been found suitable for use as the PLC. The PLC includes a base unit having a plurality of power, processing and input/out (I/O) modules mounted therein. More specifically, the base unit includes a CPU module, a power supply module, one or more input modules, one or more output modules and one or more positioning modules that are connected together by a plurality of internal buses. The input, output and positioning modules are electrically connected by wiring to the carriage 50, the shutter doors 64 and other devices in the zone 20 and are operable to transmit and receive signals to and from the foregoing. More specifically, the input module(s) are connected by wiring to the contacts of the shutter doors 64 and other devices to receive status information therefrom, while the output modules are connected by wiring to the drive means for the lowerator 56 and other devices to provide commands thereto. The positioning module(s) are connected to the servo motor

for the carriage 50 and other servo devices of the autoloader 10 to control the same in conjunction with commands from the CPU module.

The CPU module implements control strategies for the autoloader utilizing a control program written in a PLC language or a combination of PLC languages. Suitable PLC languages include ladder diagram, structured text, function block diagram, instruction list and sequential function (or flow) chart (SFC) and combinations of the foregoing. Preferably, the control program and the PLC language(s) are compatible with IEC61131 standards. When a Mitsubishi Q2AS CPU s-1 is used, a ladder diagram language that utilizes function blocks (application instructions) may be used as the PLC language. One of the application instructions that is used in the present invention is known as the FIFW instruction, which creates a data table and writes data to the end of the table with each execution of the instruction. A software package available from Mitsubishi Automation under the tradename GPP-WIN is used to program a Mitsubishi Q2AS CPU s-1 PLC.

The control system 40 is connected to by the wiring 62 to the carriage 50 for transmitting and receiving control signals to and from the carriage 50. The control system 40 is operable to control the movement of the carriage 50 along the monorail 52 and to control the operation of the lowerator 56 and the grippers 58, 60. With regard to each of the workstations MC1-MC4, the control system 40 is operable to control the carriage 50 and the grippers 58, 60 such that the carriage 50 can load and unload workstation MC1 in the manner described below. First, the gripper 58 grasps a workpiece in the input area 66 and then the lowerator 56 (with the workpiece) moves upward to the travel position. While the lowerator 56 is in the travel position, the carriage 50 moves to the workstation MC1. The lowerator 56 then moves downward to the servicing position, wherein the grippers 58, 60 enter the workstation MC1 through the entrance area. The gripper 60 grasps a worked-upon workpiece that is already present in the workstation MC1 and then removes the worked-upon workpiece from the workstation MC1. The gripper 58 loads the workpiece from the input area 66 into the workstation MC1 and then the lowerator 56 (with the worked-upon workpiece)

moves upward into the travel position. While the lowerator 56 is in the travel position, the carriage 50 moves to the drop-off station 68. At the drop-off station 68, the lowerator 56 moves downward to the servicing position and the gripper 60 releases the worked-upon workpiece so as to deposit the worked-upon workpiece at the drop-off station 68. The worked-upon workpiece is then stamped by the stamping machine 80 with a stamp indicative of the workstation MC1.

The control program of the control system 40 controls the provision of workpieces to the workstations by the autoloader 10. Initially, it should be noted that in the control program, each of the workstations MC1-MC4 is assigned a tag in the form of a unique fixed number. Whenever the control system 40 receives a call signal from one of the workstations MC1-MC4, the control program enters the tag for the workstation that transmitted the call signal into a FIFO data table (at step 125_of the supply routine 120 described below) using an FIFW application instruction. As set forth above, the FIFW instruction enters the tag at the end of the FIFO data table. In this manner, tags in the data table are arranged in chronological order, i.e., the workstation tag for the oldest received call signal is disposed at the beginning of the data table. Whenever the control system 40 receives an error signal from a workstation whose tag is entered in the FIFO data table, the control program removes the tag from the FIFO data table.

The control program controls the provision of workpieces to the workstations MC1-MC4 in accordance with the order in which call signals are received from the workstations MC1-MC4. More specifically, the control program in the CPU module controls the autoloader 10 using a supply routine 120 depicted by the flowchart shown in Figs. 5 and 6. At step 121, the supply routine 120 initiates. At step 122, the autoloader 10 is located in the input area 66, the gripper 58 is holding a selected one of the workpieces and the supply routine 120 looks for a call signal from one of the workstations MC1-MC4. Next, in decision step 124, the supply routine 120 determines if a call signal from a workstation has been received. If the supply routine 120 determines that a call signal has not been received, the supply routine 120 moves back to step 122. If a call signal

has been received, the supply routine 120 moves to step 125, where the supply routine 125 enters the tag for the workstation that transmitted the call signal into the FIFO data table. At step 126, the supply routine 120 selects the tag at the top of the FIFO data table (which corresponds to the oldest received call signal). At step 128, the selected tag is removed from the data table. Continuing, the supply routine 120 moves to step 130 and generates a movement command signal that is transmitted to the autoloader 10 and causes the carriage 50 to move to a waiting position located over a selected one of the workstations that corresponds to the selected tag. At step 132, the supply routine 120 looks to see if the control system 40 has received any signals from the selected workstation. Next, in decision step 134, the supply routine 120 determines if the control system 40 has received a ready signal, an error signal, or a shutter door 64 closed signal from the selected workstation. If the supply routine 120 determines that no signals have been received, the supply routine 120 moves back to step 132. If the supply routine 120 determines that an error signal or a shutter door 64 closed signal has been received, the supply routine 120 moves back to step 124 (however, the carriage 50 maintains its position over the current selected one of the workstations and remains there until another movement command signal is received from step 130). If the supply routine 120 determines that a ready signal has been received from the selected workstation, the supply routine 120 moves to step 136 and generates an unload/load command signal that is transmitted to the autoloader 10. In response to the unload/load command, the lowerator 56 moves downward to the servicing position. The gripper 60 then removes any worked-upon workpiece from the selected workstation and the gripper 58 loads the selected workpiece into the workstation. The lowerator 56 then moves upward to the travel position. Once the lowerator 56 is in the travel position, the supply routine 120 moves to decision step 138, wherein the supply routine 120 determines whether the gripper 60 has a worked-upon workpiece. If the supply routine 120 determines that the gripper 60 does not have a worked-upon workpiece, the supply routine 120 moves ahead to step 146. If the supply routine 120 determines that the gripper has a worked-upon workpiece, the supply routine

120 moves to step 140, wherein the supply routine 120 generates a second movement command that is transmitted to the autoloader 10 and causes the carriage 50 to move to the drop-off station 68. When the carriage 50 is at the drop-off station 68, the supply routine 120 moves to a subsequent step 142 and generates a deposit command that is transmitted to the autoloader 10. In response to the deposit command, the lowerator 56 moves downward to the servicing position and the gripper 60 deposits the worked-upon workpiece on the drop-off station 68. The lowerator 56 then moves upward to the travel position. At step 144, the supply routine 120 generates a stamp signal that is transmitted to the stamping machine 80 located at the drop-off station 68. In response to the stamp signal, the stamping machine 80 stamps the worked-upon workpiece with a mark indicating that the worked-upon workpiece was worked on by the selected workstation.

After step 144, the supply routine 120 moves to step 146 and generates a third movement command that is transmitted to the autoloader 10 and causes the carriage 50 to move to the input area 66. Once the carriage 50 is in the input area 66, the supply routine 120 moves to decision step 148, wherein the supply routine 120 determines whether a QC signal has been received. If the supply routine 120 determine that no QC signal has been received, the supply routine 120 moves to step 150 and generates a pick-up command that is transmitted to the autoloader 10. In response to the pick-up command, the lowerator 56 moves downward to the servicing position and the gripper 58 picks up another selected one of the workpieces from the input area 66. The lowerator 56 then moves upward to the travel position. At this point, the supply routine 120 moves back to step 122.

If, at decision step 148, the supply routine 120 determines that a QC signal has been received, the control program moves to a QC routine 200 depicted by the flowchart shown in Fig. 7. At decision steps 202, 204, 206, the QC routine 200 respectively determines whether the QC signal is a workstation unload signal, a workstation load signal, or a drop-off signal.

If, at step 202, it is determined that a workstation unload signal is received, the QC routine 200 moves to step 208 and generates a QC movement command that is transmitted to the autoloader 10. In response to the QC movement command, the carriage 50 moves to a selected one of the workstations for which the workstation unload signal was transmitted. At step 210, the QC routine 200 generates and transmits a QC unload command to the autoloader 10, which causes the lowerator 56 to move downward to the servicing position. The gripper 58 then removes a to-be-inspected workpiece from the selected workstation and the lowerator 56 moves upward to the travel position. At step 212, the QC routine 200 generates and transmits a second QC movement command to the autoloader 10, which causes the carriage 50 to move to the QC station 90. Next, the QC routine 200 moves to step 214, wherein the QC routine 200 generates and transmits a QC deposit command, which causes the lowerator 56 to move downward to the servicing position. The gripper 58 then deposits the to-be-inspected workpiece at the QC station 90. The lowerator 56 then moves up to the travel position. At step 216, the QC routine 200 generates and transmits to the autoloader 10 a QC return command. In response, the carriage 50 moves to the input area 66. Once the carriage 50 is at the input area 66, the QC routine 200 moves to step 218, wherein the QC routine 200 places the selected workstation into bypass mode. After step 218, the control program moves back to step 150 of the supply routine 120.

If, at step 204, it is determined that a workstation load signal is received, the QC routine 200 moves to step 222 and generates a QC movement command that is transmitted to the autoloader 10. In response to the QC movement command, the carriage 50 moves to the QC station 90. Next, the QC routine 200 moves to step 224, wherein the QC routine 200 generates and transmits a QC removal command, which causes the lowerator 56 to move downward to the servicing position. The gripper 58 then removes a to-be-reworked workpiece from the QC station 90 and the lowerator 56 moves upward to the travel position. At step 226, the QC routine 200 generates and transmits a second QC movement command to the autoloader 10, which causes the carriage 50 to move to a

selected one of the workstations for which the workstation load signal was transmitted. Next, the QC routine 200 moves to step 228, wherein the QC routine 200 generates and transmits a QC unload/load command, which causes the lowerator 56 to move downward to the servicing position. The gripper 60 then removes a worked-upon workpiece from the selected workstation and the gripper 58 deposits the to-be-reworked workpiece at the selected workstation. The lowerator 56 then moves up to the travel position. At step 229, the QC routine 200 generates and transmits a third QC movement command to the autoloader 10, which causes the carriage 50 to move to the drop-off station 68. Next, the QC routine 200 moves to step 230, wherein the QC routine 200 generates and transmits a QC deposit command, which causes the lowerator 56 to move downward to the servicing position. The gripper 60 then deposits the worked-upon workpiece in the drop-off station 68. The lowerator 56 then moves up to the travel position. At step 231, the QC routine 200 generates a stamp signal that is transmitted to the stamping machine 80 located at the drop-off station 68. In response to the stamp signal, the stamping machine 80 stamps the worked-upon workpiece with a mark indicating that the worked-upon workpiece was worked on by the workstation for which the workstation load signal was transmitted. At step 232, the QC routine 200 generates and transmits to the autoloader 10 a QC return command. In response, the carriage 50 moves to the input area 66. Once the carriage 50 is at the input area 66, the QC routine 200 moves to step 233, wherein the QC routine 200 places the selected workstation into bypass mode. After step 233, the control program moves back to step 150 of the supply routine 120.

If, at step 206, it is determined that a drop-off signal is received, the QC routine 200 moves to step 234 and generates a QC movement command that is transmitted to the autoloader 10. In response to the QC movement command, the carriage 50 moves to the QC station 90. Next, the QC routine 200 moves to step 236, wherein the QC routine 200 generates and transmits a QC removal command, which causes the lowerator 56 to move downward to the servicing position. The gripper 58 then removes a compliant workpiece from the QC station

90 and the lowerator 56 moves upward to the travel position. At step 238, the QC routine 200 generates and transmits a second QC movement command to the autoloader 10, which causes the carriage 50 to move to the drop-off station 68. Next, the QC routine 200 moves to step 240, wherein the QC routine 200 generates and transmits a QC deposit command, which causes the lowerator 56 to move downward to the servicing position. The gripper 58 then deposits the compliant workpiece in the drop-off station 68. The lowerator 56 then moves up to the travel position. At step 242, the QC routine 200 generates a stamp signal that is transmitted to the stamping machine 80 located at the drop-off station 68. In response to the stamp signal, the stamping machine 80 stamps the compliant workpiece with a mark indicating that the compliant workpiece was worked on by the workstation for which the drop-off signal was transmitted. After step 242, the QC routine 200 moves to step 244, wherein the QC routine 200 generates a return command and transmits it to the autoloader 10, which causes the carriage 50 to move to the input area 66. Once the carriage 50 is at the input area 66, the control program moves back to step 150 of the supply routine 120.

The operation of the supply routine 120 will now be explained with reference to Fig. 8. In all of the frames A, B, C, call signals from the workstations MC1-MC4 are received by the control system 40 in the order MC2, MC4, MC3, MC1, MC2, MC4, MC3, MC1. In frame A, normal operation of the autoloader 10 is depicted. The control system 40 controls the autoloader 10 to supply the workstations MC1-MC4 with workpieces in the order in which the call signals are received, namely MC2, MC4, MC3, MC1. In frame B, MC2 sends an error signal to the control system 40 at the same time or very soon after it sends its call signal. The error signal causes the control program to remove the tag for MC2 from the FIFO data table. As a result, when the supply routine 120 moves to step 126 and selects the tag at the top of the FIFO data table, the supply routine 120 will select the tag for MC4 (which has now moved to the top, since the tag for MC2 has been removed). Accordingly, the control system 40 controls the autoloader 10 to supply workpieces in the order MC4, MC3, MC1. In frame C, MC1 sends an error signal to the control system 40 after the carriage 50 has

moved to the waiting position over MC1 after step 130 of the supply routine 120. At step 132, however, the supply routine 120 finds the error signal. Therefore, at step 134, the supply routine 120 moves back to step 124. At step 126, supply routine 120 selects the tag currently at the top of the FIFO data table, which is the tag for MC2. Accordingly, the control system 40 controls the autoloader 10 to supply workpieces in the order MC2, MC4, MC3, MC2.

Routines substantially similar to the supply routine 120 and the QC routine 200 described above are performed by the control systems for the autoloaders 28, 30, 32 and other autoloaders in the machining line 22. Thus, when a workpiece travels from zone to zone, the workpiece is stamped with markings in a manner indicating the workstations that worked on the workpiece in each of the zones. Preferably, the markings are made in accordance with predetermined unique codes for the workstations, wherein each unique code is a combination of the location of a mark on the workpiece and the type or nature of the mark. More specifically, the workpiece includes a plurality of marking areas and positions, wherein each area or position in an area represents a zone in the machining line 22. The mere presence of a mark in a marking area or position in a marking area indicates a particular zone. The type or nature of the mark specifies the particular machine in the zone. The marking areas are selected based on a number of criteria, such as: (i.) not being in a critical location that would affect the utility of the workpiece, (ii.) being in a location where markings will not be machined off in future operations, (iii.) when the workpiece sits on the output conveyor 36 (and other output conveyors), the marking areas are visible to operators, and (iv.) being in a location that can easily be seen when the workpiece is in a heat treatment basket (if the operation is before heat treatment).

With specific regard to the workpiece being a crankshaft, such as a crankshaft 250 (shown in Figs. 9-11), the crankshaft 250 is provided with a plurality of stamp marking areas 252, 254, 256, 258, 260, 262, 264, within which the stamping machine 80 and other stamping machines of the machining line 22 make marks. Stamp marking areas 252, 254 and 256 are located on a counterweight 266 (shown in Fig. 10), located toward a first end of the crankshaft

250, while stamp marking areas 258, 260, 262, 264 are located on a counterweight 268 (shown in Fig. 11), located toward an opposing second end of the crankshaft 250. Stamp marking areas 252-256 each contain a plurality of positions, wherein each position represents a zone. Stamp marking areas 258-264 each only contain one position and, thus, each represent a zone. In stamp marking area 254, position A represents a zone of the machining line 22 that is not shown, such as a zone containing a pair of burnish machines, while position B represents the preceding zone 24 and position C represents the zone 20. In stamp marking area 256, positions A, C and D represent zones of the machining line 22 that are not shown, such as a zone containing multiwheel grinders, a zone containing pin grinders and a zone containing flange grinders, respectively, while position B represents zone 26.

Preferably, the marks made by the stamping machine 80 and other stamping machines in the machining line 22 are numeric characters, more preferably single digit numerals. For example, in zone 20, the marks for workstations MC1-MC8 may be 1-8, respectively, in the preceding zone 24, the marks for workstations MC9-MC11 may be 1-3, respectively, and in the following zone 26, the marks for workstations MC12 and MC13 may be 1 and 2, respectively. In this regard, it should be noted that the marks for the workstations in the machining line 22 do not have to be unique for the entire machining line 22; the marks only have to be unique for a particular zone (mark stamping area).

Based on the foregoing system, if the numbers 1, 2, 3 are present in stamp marking area 254, an operator knows, inter alia, that the crankshaft 250 was worked on by MC10 and MC3. If the numbers 1, 2, 3, 4 are present in stamp marking area 256, the operator knows, inter alia, that the crankshaft 250 was worked on by MC13.

In addition to the stamp marking areas 252-264, the crankshaft contains alternate marking areas 270, 272, 274, 276 (shown in Fig. 11), within which marks are made by marking devices other than stamping machines. Each of the alternate marking areas 270-274 represents a particular workstation and the presence or absence of a mark in the area indicates whether the workstation

worked on the crankshaft 250. For example, alternate areas 270, 272, 274 may represent balance machines A, B, C, respectively, and the presence of a drill mark in alternate marking area 272 informs an operator that balance machine B worked on the crankshaft 250.

The marking system described above may be interpreted automatically by an identification apparatus, or may be interpreted by an operator. If the marking system is interpreted by an operator, the operator may be provided with an interpretation key in some form of a fixed medium, such as diagrams on paper, similar to Figs. 10 and 11, or in a computer file that may be viewed on a computer display.

Preferably, a workpiece moving through the machining line 22 is marked at the drop-off station of each zone (by a stamping machine or otherwise) to indicate the workstation that worked on the workpiece in the zone. Thus, for purposes of describing only a portion of the machining line 22, the crankshaft 250 is moved by the autoloader 10 from the input area 66 to the workstation MC2. The crankshaft 250 is worked on in workstation MC2 and is then moved by the autoloader 10 to the drop-off station 68, where the crankshaft 250 is stamped by the stamping machine 80 with a numeral 2 in position C of stamping area 254. The crankshaft 250 is then moved by the output conveyor 36 from the drop-off station 68 to the second input area 70. The autoloader 32 moves the crankshaft 250 from the second input area 70 to the workstation MC12, where the crankshaft 250 is worked on. The autoloader 32 then moves the crankshaft 250 to the second drop-off station 74, where the crankshaft 250 is stamped by a stamping machine (having substantially the same construction and operation as the stamping machine 80) with a numeral 1 in position B of stamping area 256. The crankshaft 250 is then moved by the output conveyor 72 from the second drop-off station 74 to another zone, where the crankshaft 250 will be moved by another autoloader to another workstation. This process continues until the crankshaft 250 is finished.

The marking process described above will produce a workpiece having a plurality of markings that can be used by an operator to determine every specific

workstation that worked on the workpiece. In this manner, if a finished workpiece exits the machining line 22 and is later found to have a defect caused by a particular operation, the operator can determine the specific workstation that caused the defect. As can be appreciated, this significantly helps maintain the quality of workpieces being produced by the machining line 22.

While the invention has been shown and described with respect to particular embodiments thereof, those embodiments are for the purpose of illustration rather than limitation, and other variations and modifications of the specific embodiments herein described will be apparent to those skilled in the art, all within the intended spirit and scope of the invention. Accordingly, the invention is not to be limited in scope and effect to the specific embodiments herein described, nor in any other way that is inconsistent with the extent to which the progress in the art has been advanced by the invention.